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WIND-TUNNEL TESTS OF A HALL HIGH-LIFT WING

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SUMMARY

Wind-tunnel tests have been made to find the lift, drag, and center-of-pressure characteristics of a Hall high-lift wing model. The Hall wing is essentially a split-flap airfoil with an internal air passage. Air enters the passage through an opening in the lower surface somewhat back of and parallel to the leading edge, and flows out through an opening made by deflecting the rear portion of the under surface downward as a flap. For ordinary flight conditions the front opening and the rear flap can be closed, providing in effect a conventional airfoil (the Clark Y in this case). The tests were made with various flap settings and with the entrance to the passage both open and closed. The highest lift coefficient found, C_L = 2.08, was obtained with the passage closed.

INTRODUCTION

The present Hall high-lift wing is the result of a development which started with a study by Theodore P. Hall of the possibilities of converting the upper and lower surfaces of the conventional wing into separate airfoils, forming in effect a biplane combination with a small gap. (Reference 1.) The development was continued with the construction of an airplane incorporating the wing shown in Figure 1, which was entered in the Guggenheim safety competition. (Reference 2.) The flaps on this airplane were later made automatic in operation. More recently, further wind-tunnel tests have been made on a small model of the Hall wing in its latest form (similar to that in fig. 2). In both the wind-tunnel and flight tests substantially higher lift coefficients were obtained with the high-lift arrangements than with conventional wings, but the approximate nature of the flight tests and the low scale of the wind-tunnel tests made further experiments desirable.

The present tests have been made as part of a series on various high-lift devices in the N.A.C.A. 7 by 10 foot wind tunnel. The latest form of Hall high-lift wing was tested with the flap set at various angles, and the entrance to the internal passage both open and closed.

APPARATUS AND METHODS

The Hall wing model, which was constructed of laminated mahogany (figs. 2 and 3) had a chord of 10 inches and a span of 60 inches. Narrow ribs in the internal passage were spaced about 3 inches apart. In the center of the wing a 4-inch cell was made solid for mounting. The rear flap was supported on hinges ahead of its leading edge. Thus when deflected there was a gap between the flap and the lower surface of the wing, which is not the case with the wing on the Cunningham-Hall airplane. (Fig. 1.) In the model the flaps were hinged at eight points along the span and provided with small quadrants having holes drilled 10° apart for deflections from 0° to 50°. For one test the slope of the upper surface of the passage just above the front portion of the flap was increased from 26° to 45° by means of Plasticine. (Shown in fig. 3 and in an insert of fig. 2.) The front entrance to the passage was closed by means of a cover plate, making the wing in effect a conventional airfoil with a split flap. The cover plate was used on the model to replace a forward vane or valve; with the plate removed the inside form of the passage simulated that with the vane displaced 30° upward.

The 7 by 10 foot wind tunnel is of the open-jet type and is described in detail together with the balances and standard test procedure in reference 3. The Hall wing model, which lacked rigidity because of its hollow construction, was supported by a fine wire at each wing tip in addition to the usual center support. The tests were made at an air speed of 80 miles per hour, corresponding to a Reynolds Number of 609,000.

RESULTS AND DISCUSSION

The values of C_L, C_D, and c.p. are plotted against angle of attack for the various flap settings with the passage open in Figure 4 and with the passage closed in Figure

5. No tunnel-wall correction was made.

Lift. - From the cross plots of the maximum lift coefficients against flap setting given in Figure 6, it can be seen that the highest value of $C_{L\ max}$ with the passage open is 2.05 and occurs with a flap angle of about 45°. This is a 60 per cent increase over the maximum lift coefficient of 1.28 obtained with the basic Clark Y wing. With the passage closed the highest value of $C_{L\ max}$ is 2.08 with a flap setting of about 48°.

Changing the slope of the upper surface of the passage just above the front portion of the flap from 26° to 45° made no appreciable difference in the characteristics of the wing.

It is interesting to compare the highest value of $C_{L\ max}$ obtained with the Hall form of flap (2.08) with the value obtained in tests of a conventional trailing-edge flap on a Clark Y airfoil. (Reference 4.) The tests which were made at the same air speed and with models of the same chord, gave a value of $C_{L\ max}$ of 1.95 with the plain flap. The chord of the conventional flap was 30 per cent of the wing chord, and the flap was depressed 45°. The actual chord of the Hall flap was 34 per cent of the wing chord but the over-all distance from the hinge axis to the trailing edge was 41 per cent of the wing chord.

Drag. - The minimum drag coefficient of the Hall wing model with the cover plate in place and the flap neutral was 0.0161, as compared with the value 0.0150 obtained under the same test conditions with a solid Clark Y airfoil. Thus the extra drag due to the flap supports and to the slight imperfections of section accompanying the split form of flap was approximately 7 per cent.

A point of interest is the high drag at maximum lift with the flap down. At the peak of the lift curve the value of L/D with the flap in the position giving the highest maximum lift was less than one-half that of the plain wing at the peak of its lift curve, making possible a much steeper approach for a landing.

Center of presure. - The center of pressure with the flap down 20° or more was back about 10 per cent of the chord from its location with the flap up. This was approximately true for any angle of attack above 0° whether the passage through the wing was open or closed.

CONCLUSIONS

1. The highest lift coefficient obtained with the model of the Hall high-lift wing tested was of the order of that obtained with a conventional trailing-edge flap.

2. Slightly higher values of the maximum lift coefficient were obtained with the passage through the wing closed than with it open.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., March 31, 1932.

REFERENCES

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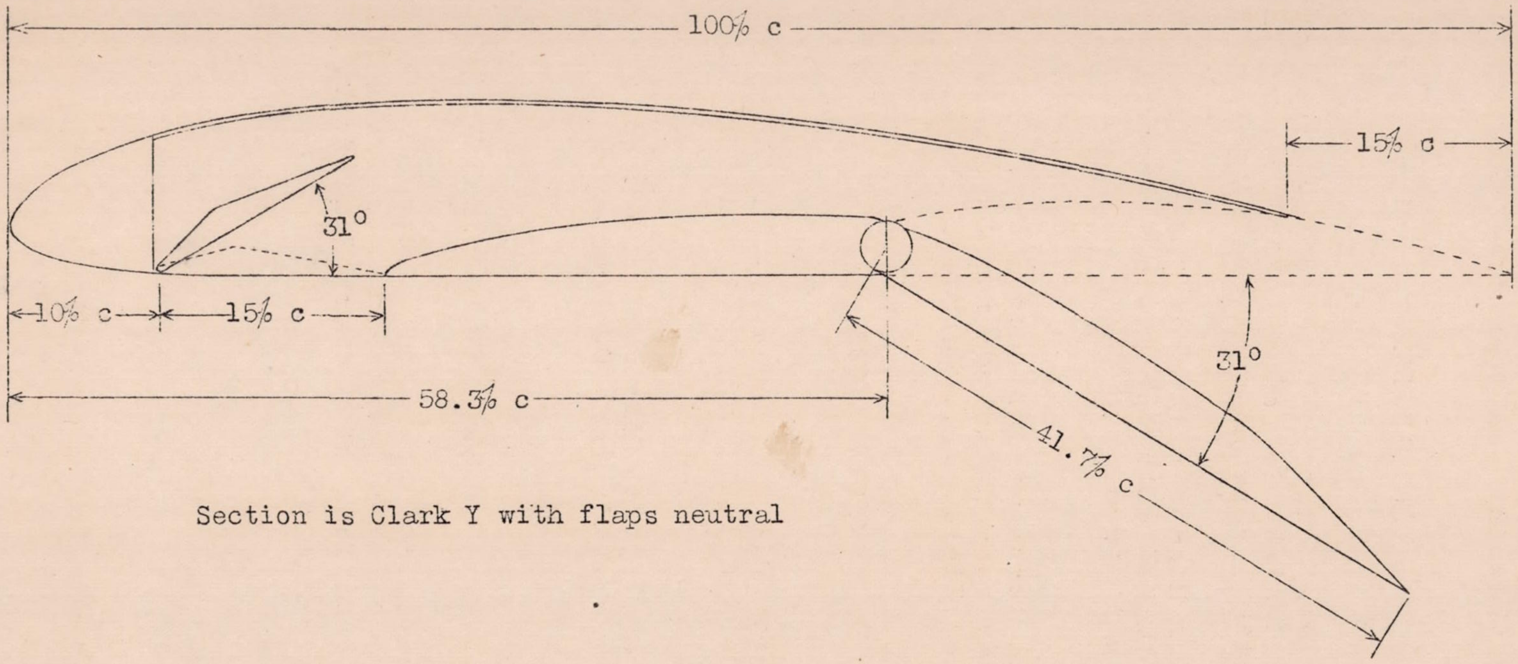
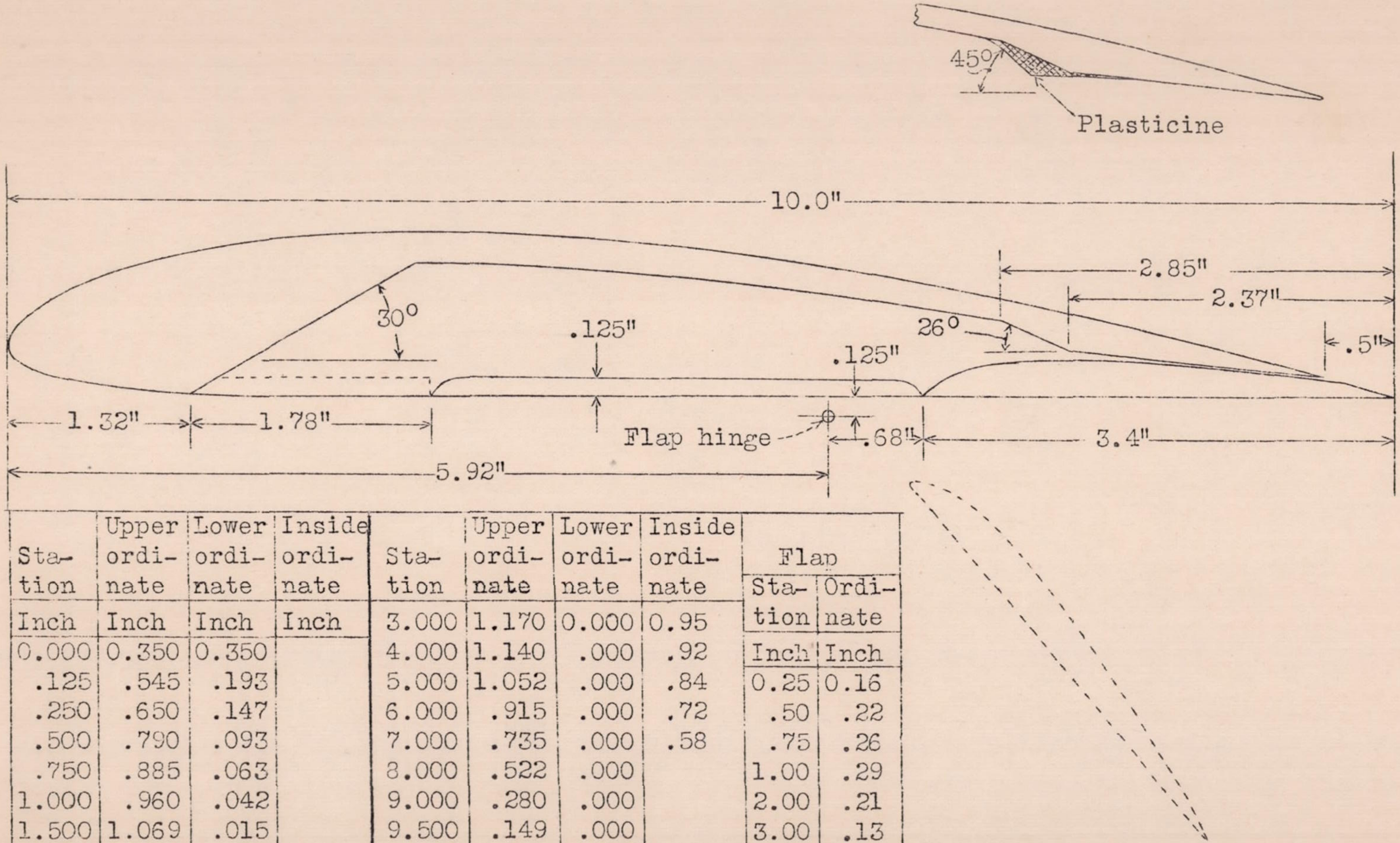
3. Harris, Thomas A.: The 7 by 10 Foot Wind Tunnel of the N.A.C.A. T.R. No. 412, N.A.C.A., 1931.

4. Weick, Fred E., and Shortal, Joseph A.: The Effect of Multiple Fixed Slots and a Trailing-Edge Flap on the Lift and Drag of a Clark Y Airfoil. T.R. No. 427, N.A.C.A., 1932.



Section is Clark Y with flaps neutral

Fig.1 Section of wing used on Cunningham-Hall airplane.



Station	Upper ordinate	Lower ordinate	Inside ordinate
Inch	Inch	Inch	Inch
0.000	0.350	0.350	
.125	.545	.193	
.250	.650	.147	
.500	.790	.093	
.750	.885	.063	
1.000	.960	.042	
1.500	1.069	.015	
2.000	1.136	.003	

Station	Upper ordinate	Lower ordinate	Inside ordinate
3.000	1.170	0.000	0.95
4.000	1.140	.000	.92
5.000	1.052	.000	.84
6.000	.915	.000	.72
7.000	.735	.000	.58
8.000	.522	.000	
9.000	.280	.000	
9.500	.149	.000	
10.000	.012	.000	

Flap	
Station	Ordinate
Inch	Inch
0.25	0.16
.50	.22
.75	.26
1.00	.29
2.00	.21
3.00	.13
3.40	.01

L.E. radius = 0.15 inch

Fig. 2 Section of Hall high-lift wing model. Dotted lines indicate flap set at 50° and closed passage.

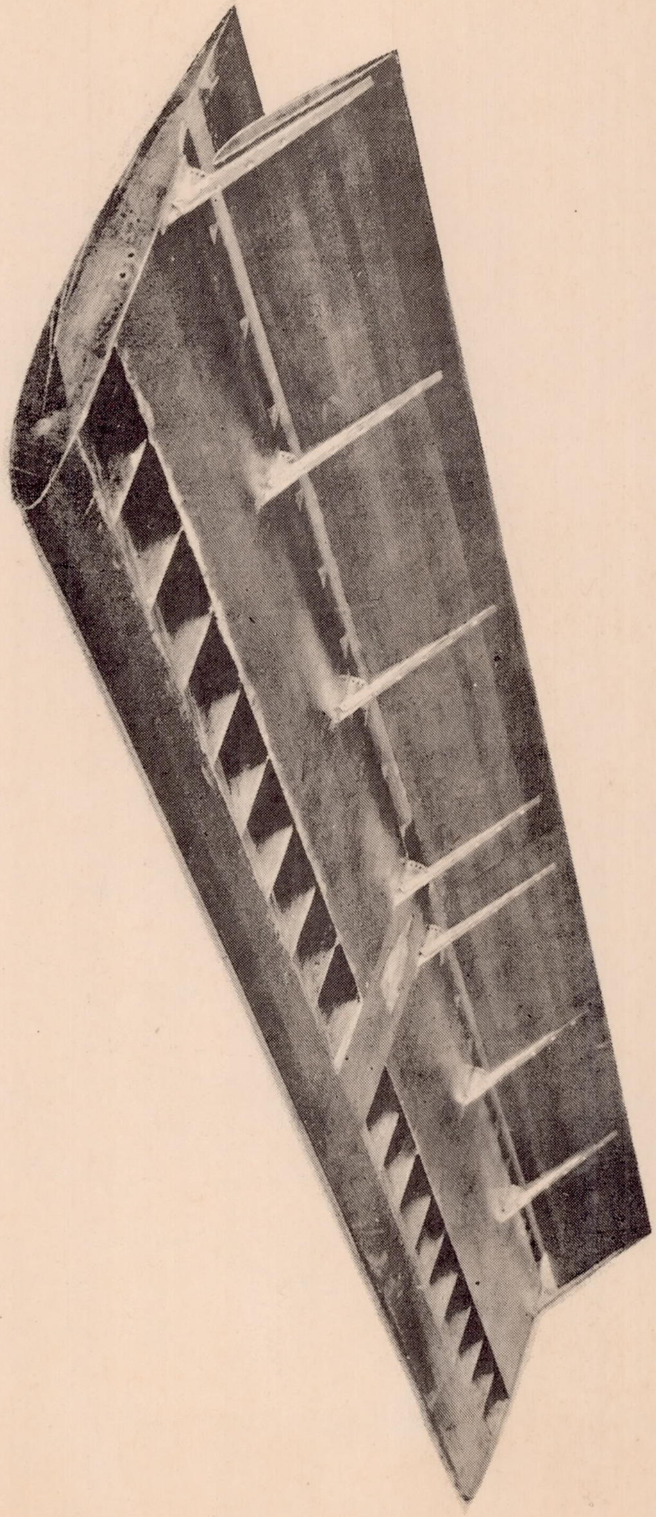


Fig. 3 Model of Hall high-lift wing.

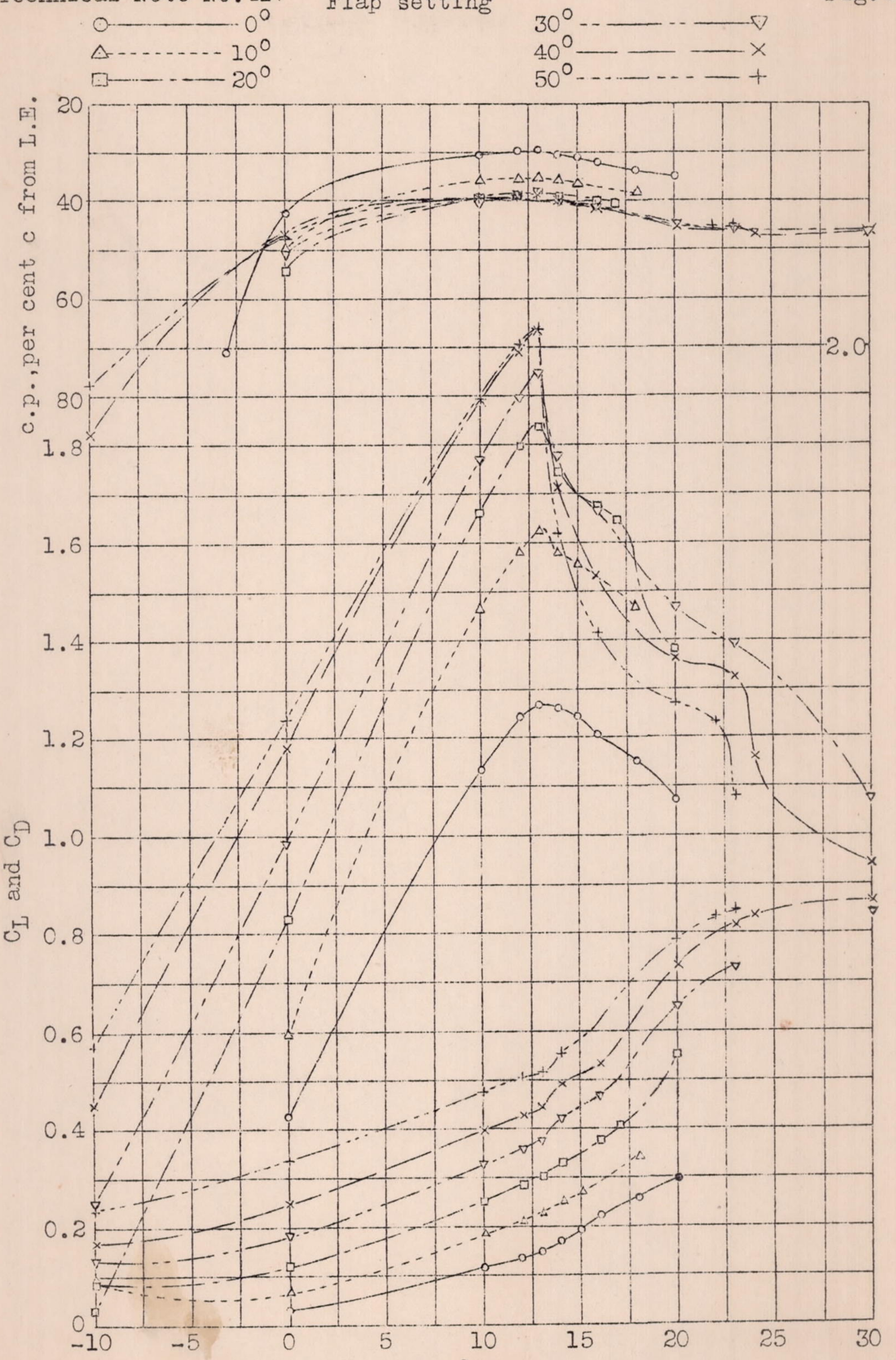


Fig.4 Characteristics of 10 in. by 60 in. Hall wing with passage open and flap at various angles uncorrected for tunnel wall effect.

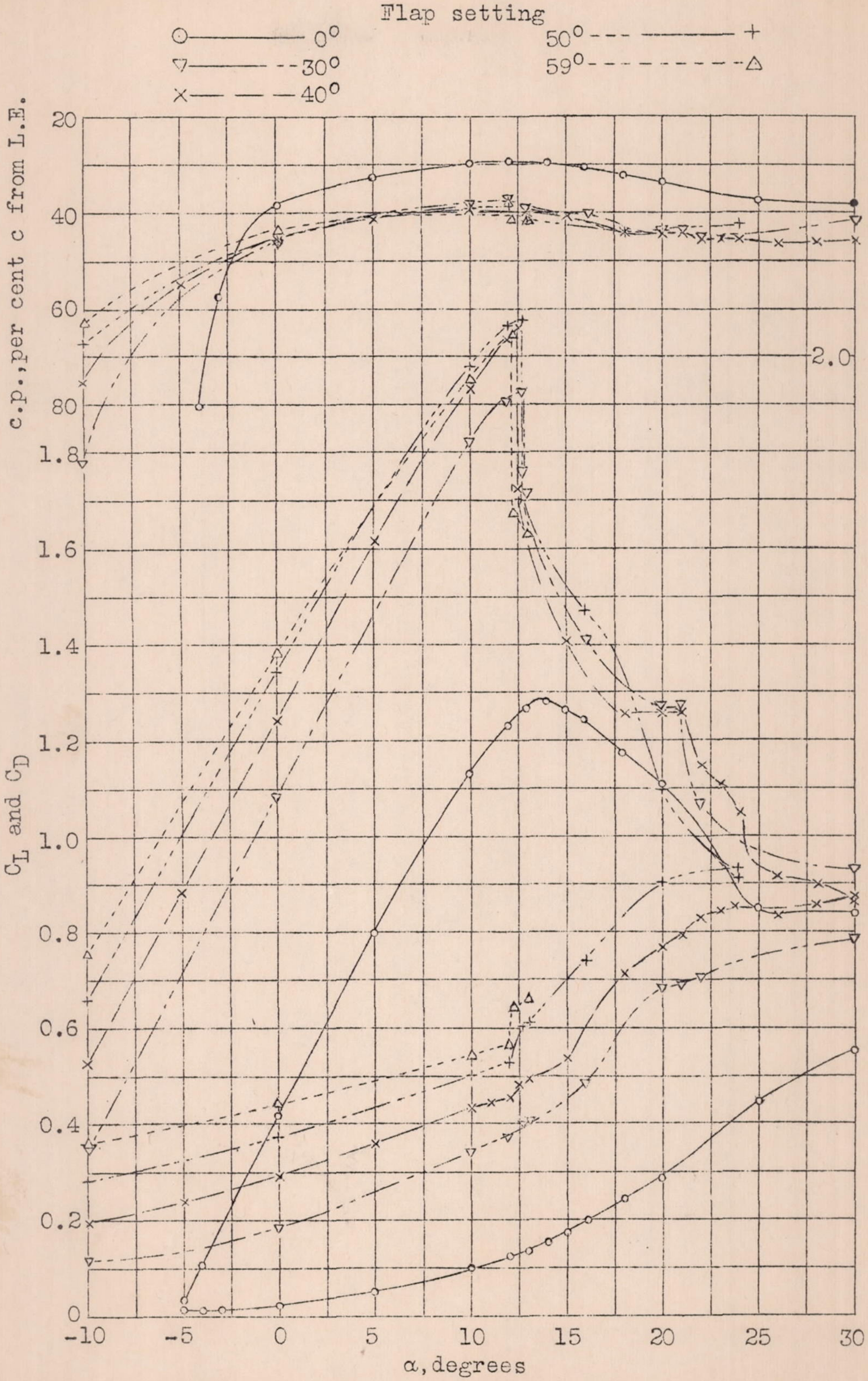


Fig.5 Characteristics of 10 in. by 60 in. Hall wing with passage closed and flap at various angles uncorrected for tunnel wall effect.

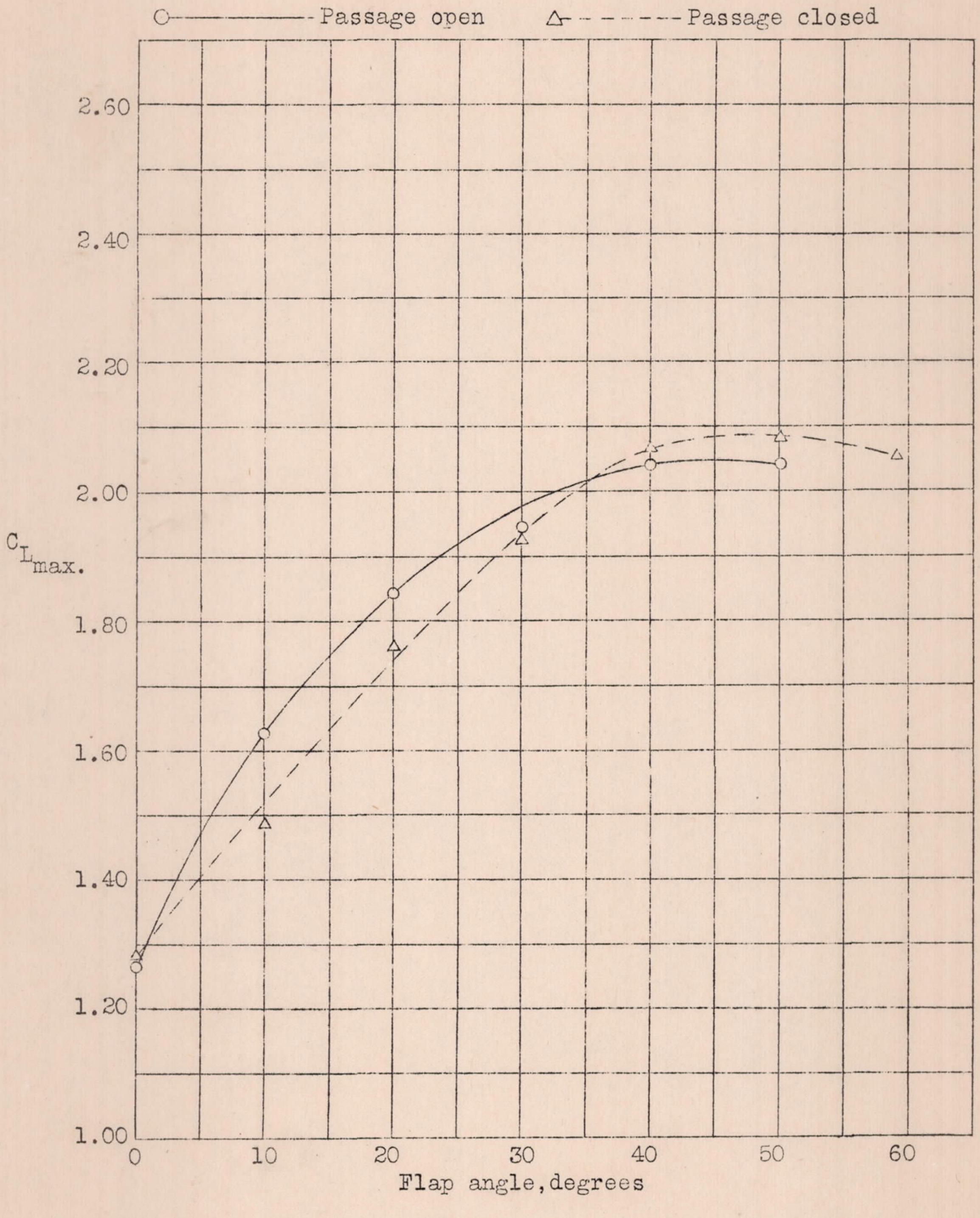


Fig.6 Variation of maximum lift coefficient with flap angle.